

TPS7H1201-HT 1.5-V to 7-V Input, Ultra-Low Dropout (LDO) Regulator

1 Features

- Wide V_{IN} Range: 1.5 V to 7 V
- Current Share/Parallel Operation to Provide Higher Output Current
- Stable With Ceramic Output Capacitor
- $\pm 4.2\%$ Accuracy Over Line, Load, and Temperature
- Programmable Soft-Start
- Power-Good Output
- LDO Voltage:
100 mV (Max) at 0.5 A (210°C), $V_{OUT} = 6.8$ V
- Low Noise:
20.26 μ V_{RMS} $V_{IN} = 2.1$ V, $V_{OUT} = 1.8$ V at 0.5 A
- PSRR: Over 45 dB at 1 kHz
- Load/Line Transient Response
- See the [Tools & Software](#) Tab

2 Applications

- RF 5-V Components VCOs, Receivers, ADCs, Amplifiers
- Clock Distribution
- Clean Analog Supply Requirements
- Supports Harsh Environment Applications
- Available in Extreme (–55°C to 210°C) Temperature Range⁽¹⁾
- TI's High-Temperature Products Use Highly-Optimized Silicon (Die) Solutions With Design and Process Enhancements to Maximize Performance Over Extended Temperatures

3 Description

The TPS7H1201-HT is a LDO linear regulator that uses a PMOS pass element configuration. This device operates over a wide range of input voltage, from 1.5 V to 7 V while offering excellent PSRR.

The TPS7H1201-HT features a precise and programmable foldback current limit implementation with a very-wide adjustment range. To support the complex power requirements of FPGAs, DSPs, or microcontrollers, the TPS7H1201-HT provides enable on and off functionality, programmable SoftStart, current sharing capability, and a PowerGood open-drain output.

The TPS7H1201-HT is available in a thermally-enhanced 16-pin ceramic flatpack package (CFP) and KGD (bare die) package.

Device Information⁽²⁾

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TPS7H1201-HT	CFP (16)	11.00 mm × 9.60 mm

(1) Custom temperature ranges are available

(2) For all available packages, see the orderable addendum at the end of the data sheet.

Typical Application Circuit

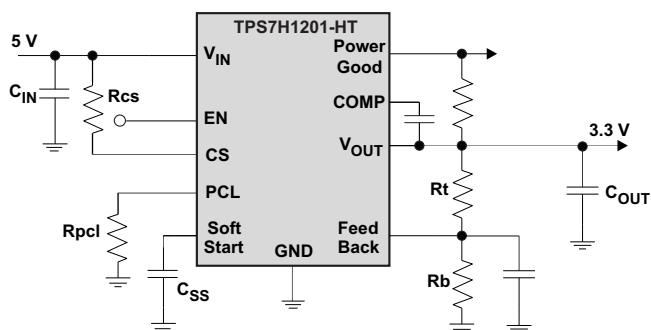


Table of Contents

1 Features	1	8 Application and Implementation	14
2 Applications	1	8.1 Application Information.....	14
3 Description	1	8.2 Typical Application	15
4 Revision History	2	9 Power Supply Recommendations	25
5 Pin Configuration and Functions	3	10 Layout	25
6 Specifications	6	10.1 Layout Guidelines	25
6.1 Absolute Maximum Ratings	6	10.2 Layout Example	25
6.2 ESD Ratings.....	6	11 Device and Documentation Support	26
6.3 Recommended Operating Conditions.....	6	11.1 Device Support.....	26
6.4 Thermal Information	6	11.2 Documentation Support	26
6.5 Electrical Characteristics.....	7	11.3 Receiving Notification of Documentation Updates	26
6.6 Typical Characteristics	9	11.4 Community Resources.....	26
7 Detailed Description	11	11.5 Trademarks	26
7.1 Overview	11	11.6 Electrostatic Discharge Caution.....	26
7.2 Functional Block Diagram	11	11.7 Glossary	26
7.3 Feature Description	12	12 Mechanical, Packaging, and Orderable Information	27
7.4 Device Functional Modes.....	12		

4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

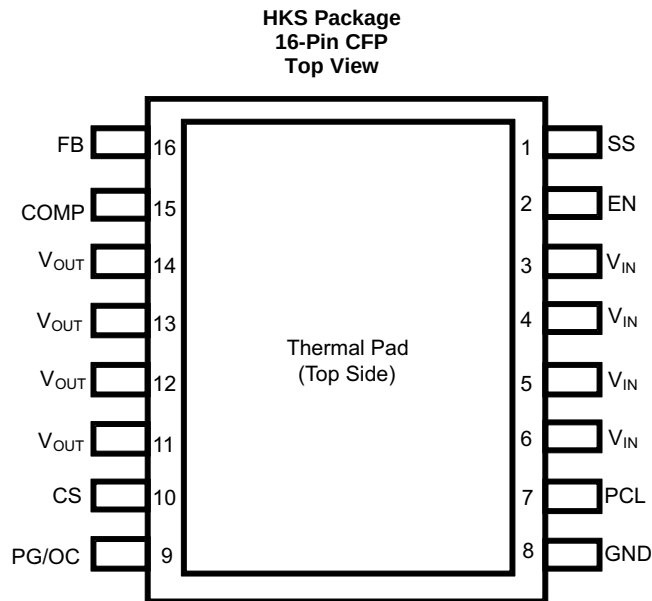
Changes from Revision I (January 2016) to Revision J	Page
• Changed output voltage MAX from V_{IN} : to 7.5 V in <i>Absolute Maximum Ratings</i> table	6
• Deleted peak output current spec in <i>Absolute Maximum Ratings</i> table	6
• Added rise time specifications for EN and VIN signals in <i>Recommended Operating Conditions</i> table	6
• Added test conditions to V_{ILEN} and V_{IHEN} in the <i>Electrical Characteristics</i> table	7
• Added Receiving Notification of Documentation Updates section to <i>Device and Documentation Support</i> section.....	26
• Added Device Nomenclature section to <i>Device Support</i> section (previously located in the Mechanical, Packaging, and Orderable Information section)	26
• Changed documents listed in the <i>Related Documentation</i> section	26

Changes from Revision H (December 2014) to Revision I	Page
• Removed part number from data sheet.....	1
• Corrected the thermal values for $R_{\theta JB}$	6
• Removed the ψ_{JT} thermal metric	6

Changes from Revision G (January 2014) to Revision H	Page
• Added <i>ESD Ratings</i> table, <i>Feature Description</i> section, <i>Device Functional Modes</i> , <i>Application and Implementation</i> section, <i>Power Supply Recommendations</i> section, <i>Layout</i> section, <i>Device and Documentation Support</i> section, and <i>Mechanical, Packaging, and Orderable Information</i> section	1

Changes from Revision F (December 2013) to Revision G	Page
• Added Bare Die Information	4

5 Pin Configuration and Functions



Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
SS	1	O	Soft-start terminal. Connecting an external capacitor slows down the output voltage ramp rate after enable event. The soft-start terminal can be used to disable the device as described in the Soft Start section.
EN	2	I	Enable terminal. Driving this terminal to logic high enables the device; driving the terminal to logic low disables the device. V_{IN} voltage must be greater than 3.5 V when using the EN pin. For $V_{IN} < 3.5$ V, enable terminal cannot be used to disable the device. TI recommends to connect the enable terminal to V_{IN} .
V_{IN}	3	I	Unregulated supply voltage. TI recommends to connect an input capacitor as a good analog circuit practice.
	4		
	5		
	6		
PCL	7	O	Programmable current limit. A resistor to GND sets the overcurrent limit activation point. The range of resistor that can be used on the PCL terminal to GND is 47 k Ω to 160 k Ω .
GND	8	—	Ground/thermal pad. ⁽¹⁾
PG/OC	9	O	Power Good terminal. PG is an open-drain output to indicate the output voltage reaches 90% of target. PG terminal is also used as indicator when an overcurrent condition is activated. PG pin should have a pull-up resistor to the V_{OUT} pin.
CS	10	O	Current sense terminal. Resistor connected from CS to V_{IN} . CS terminal indicates voltage proportional to output current.
V_{OUT}	11	O	Regulated output.
	12		
	13		
	14		
COMP	15	I	Internal compensation point for error amplifier.
FB	16	I	The output voltage feedback input through voltage dividers. See Adjustable Output Voltage (Feedback Circuit) section.

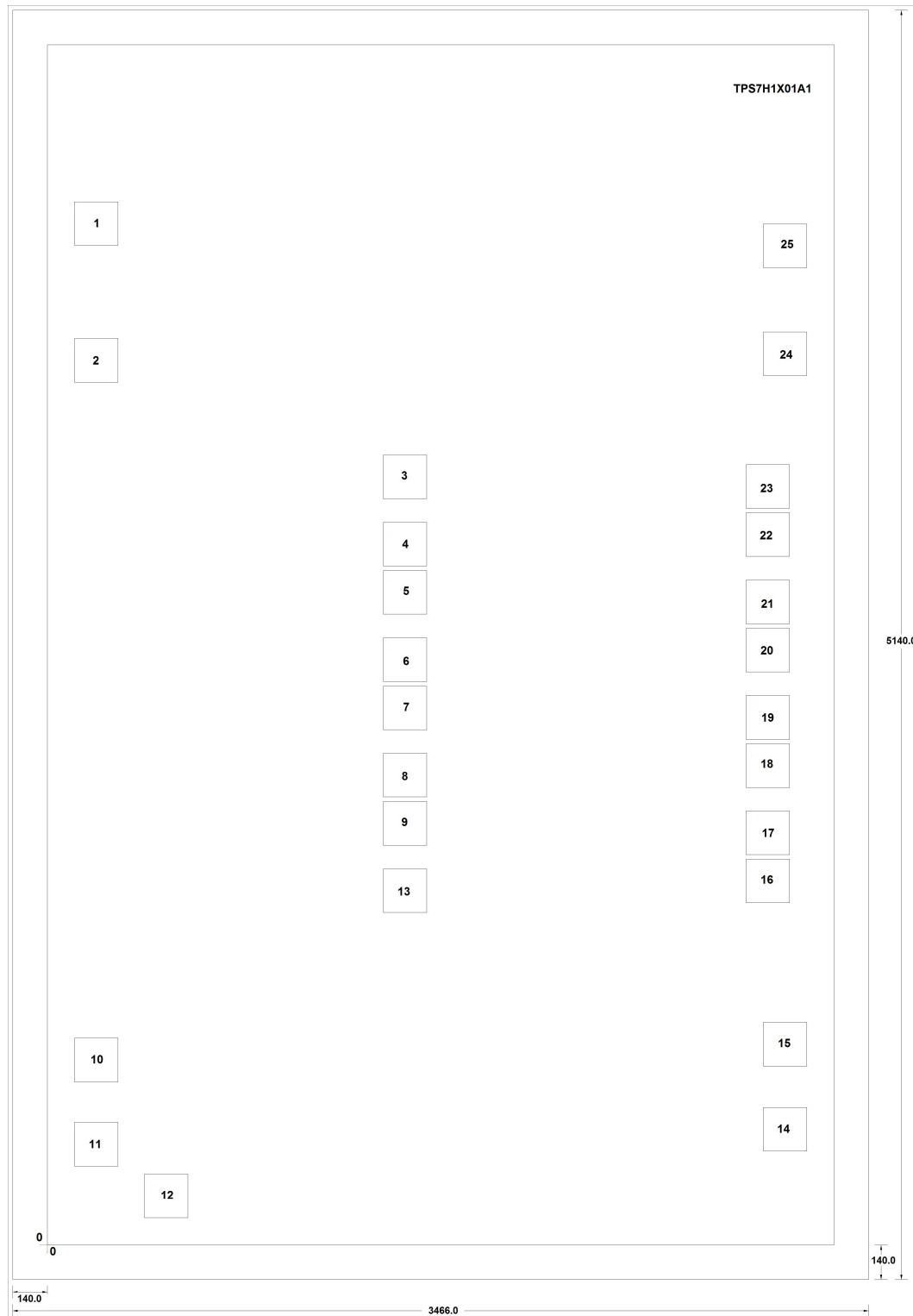
(1) Thermal pad must be connected to GND.

TPS7H1201-HT

SLVSAS4J –JUNE 2013–REVISED APRIL 2017

www.ti.com
Bare Die Information

DIE THICKNESS	BACKSIDE FINISH	BACKSIDE POTENTIAL	BOND PAD METALLIZATION COMPOSITION	BOND PAD THICKNESS
15 mils	Silicon with backgrind	Ground	AlCu	30 kÅ



NOTE: All dimensions are in microns.

Bond Pad Coordinates in Microns

DESCRIPTION	PAD NUMBER	X MIN	Y MIN	X MAX	Y MAX
SS	1	109.89	4046.805	287.19	4224.105
EN	2	109.89	3493.35	287.19	3670.65
VIN	3	1359.99	3021.345	1537.29	3198.645
VIN	4	1359.99	2749.005	1537.29	2926.305
VIN	5	1359.99	2553.705	1537.29	2731.005
VIN	6	1359.99	2281.365	1537.29	2458.665
VIN	7	1359.99	2086.065	1537.29	2263.365
VIN	8	1359.99	1813.725	1537.29	1991.025
VIN	9	1359.99	1618.425	1537.29	1795.725
PCL	10	109.89	660.285	287.19	837.585
GND	11	109.89	319.455	287.19	496.755
N/C	12	392.58	109.935	569.88	287.235
VIN	13	1359.99	1346.085	1537.29	1523.385
PG/OC	14	2898.945	379.62	3076.245	556.92
CS	15	2898.945	724.32	3076.245	901.62
VOUT	16	2829.105	1384.695	3006.405	1561.995
VOUT	17	2829.105	1579.815	3006.405	1757.115
VOUT	18	2829.105	1852.335	3006.405	2029.635
VOUT	19	2829.105	2047.455	3006.405	2224.755
VOUT	20	2829.105	2319.975	3006.405	2497.275
VOUT	21	2829.105	2515.095	3006.405	2692.395
VOUT	22	2829.105	2787.615	3006.405	2964.915
VOUT	23	2829.105	2982.735	3006.405	3160.035
COMP	24	2898.945	3519.72	3076.245	3697.02
FB	25	2898.945	3956.535	3076.245	4133.835

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)⁽¹⁾

		MIN	MAX	UNIT
Input voltage	V _{IN} , PG	–0.3	7.5	V
	FB, COMP, PCL, CS, EN	–0.3	V _{IN} + 0.3	V
Output voltage	V _{OUT} , SS	–0.3	7.5	V
PG terminal sink current		0.001	5	mA
Maximum operating junction temperature, T _J		–55	220	°C
Storage temperature, T _{stg}		–55	220	°C

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

6.2 ESD Ratings

		VALUE	UNIT
V _(ESD) Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins ⁽¹⁾	±2000	V
	Charged-device model (CDM), per JEDEC specification JESD22-C101, all pins ⁽²⁾	±1000	

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
T _J	Operating junction temperature	–55		210	°C
t _R EN	Rise time (10% to 90%) for EN signal	100			μs
t _R VIN	Rise time (10% to 90%) for VIN = EN	1			ms

6.4 Thermal Information

THERMAL METRIC ⁽¹⁾⁽²⁾		TPS7H1201-HT	UNIT
		HKS (CFP) ⁽³⁾	
		16 PINS	
R _{θJA}	Junction-to-ambient thermal resistance	75.4	°C/W
R _{θJC(top)}	Junction-to-case (top) thermal resistance	0.4	°C/W
R _{θJB}	Junction-to-board thermal resistance	64.8	°C/W
ψ _{JB}	Junction-to-board characterization parameter	53.5	°C/W
R _{θJC(bot)}	Junction-to-case (bottom) thermal resistance	N/A	°C/W

- (1) Maximum power dissipation may be limited by overcurrent protection.
(2) Test board conditions:
(a) 2.5 inches × 2.5 inches, 4 layers, thickness: 0.062 inch
(b) 2-oz. copper traces located on the top of the PCB
(c) 2-oz. copper ground planes on the 2 internal layers and bottom layer
(d) 48 (0.010-inch) thermal vias located under the device package
(3) Power rating at a specific ambient temperature T_A should be determined with a junction temperature below 220°C. This is the point where distortion starts to substantially increase. Thermal management of the PCB should strive to keep the junction temperature at or below 220°C for best performance and long-term reliability.

6.5 Electrical Characteristics

$1.5\text{ V} \leq V_{IN} \leq 7\text{ V}$, $V_{OUT(target)} = V_{IN} - 0.3\text{ V}$, $I_{OUT} = 10\text{ mA}$, $V_{EN} = 1.1\text{ V}$, $C_{OUT} = 22\text{ }\mu\text{F}$, PG terminal pulled up to V_{IN} with $50\text{ k}\Omega$, over operating temperature range ($T_J = -55^\circ\text{C}$ to 210°C), unless otherwise noted. Typical values are at $T_J = 25^\circ\text{C}$.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{IN} Input voltage range		1.5		7	V
V_{FB} Feedback terminal voltage	$1.5\text{ V} \leq V_{IN} \leq 7\text{ V}$	$T_J = 125^\circ\text{C}$	0.593	0.605	0.617
		$T_J = 210^\circ\text{C}$	0.580	0.605	0.630
V_{OUT} Output voltage range		0.8		$V_{IN} - 0.2$	V
Output voltage accuracy	$I_{OUT} \leq 0.5\text{ A}$, $1.5\text{ V} \leq V_{IN} \leq 7\text{ V}$, $V_{OUT} = 6.8\text{ V}^{(1)}$	$T_J = 125^\circ\text{C}$	-2%	2%	
		$T_J = 210^\circ\text{C}$	-4.2%	4.2%	
$\Delta V_{OUT}/\Delta V_{IN}$ Line regulation	$1.5\text{ V} \leq V_{IN} \leq 7\text{ V}$	-0.07	0.01	0.07	%/V
$\Delta V_{OUT}/\Delta I_{OUT}$ Load regulation	$0.8\text{ V} \leq V_{OUT} \leq 6.8\text{ V}$, $0 \leq I_{Load} \leq 0.5\text{ A}$		0.0125		%/A
ΔV_O DC input line regulation	$1.5\text{ V} \leq V_{IN} \leq 7\text{ V}$, $V_{OUT} = 0.8\text{ V}$, $I_{OUT} = 10\text{ mA}$, $T_J = -55^\circ\text{C}^{(2)}$		0.5	3	mV
	$1.5\text{ V} \leq V_{IN} \leq 7\text{ V}$, $V_{OUT} = 0.8\text{ V}$, $I_{OUT} = 10\text{ mA}$, $T_J = 25^\circ\text{C}^{(2)}$		0.2	0.6	
	$1.5\text{ V} \leq V_{IN} \leq 7\text{ V}$, $V_{OUT} = 0.8\text{ V}$, $I_{OUT} = 10\text{ mA}$, $T_J = 125^\circ\text{C}^{(2)}$		0.2	1	
	$1.5\text{ V} \leq V_{IN} \leq 7\text{ V}$, $V_{OUT} = 0.8\text{ V}$, $I_{OUT} = 10\text{ mA}$, $T_J = 210^\circ\text{C}^{(2)}$		0.84	3	
	$1.5\text{ V} \leq V_{IN} \leq 7\text{ V}$, $V_{OUT} = 1.2\text{ V}$, $I_{OUT} = 10\text{ mA}$, $T_J = -55^\circ\text{C}^{(2)}$		0.5	3	
	$1.5\text{ V} \leq V_{IN} \leq 7\text{ V}$, $V_{OUT} = 1.2\text{ V}$, $I_{OUT} = 10\text{ mA}$, $T_J = 25^\circ\text{C}^{(2)}$		0.2	0.6	
	$1.5\text{ V} \leq V_{IN} \leq 7\text{ V}$, $V_{OUT} = 1.2\text{ V}$, $I_{OUT} = 10\text{ mA}$, $T_J = 125^\circ\text{C}^{(2)}$		0.2	1	
	$1.5\text{ V} \leq V_{IN} \leq 7\text{ V}$, $V_{OUT} = 1.2\text{ V}$, $I_{OUT} = 10\text{ mA}$, $T_J = 210^\circ\text{C}^{(2)}$		0.84	3	
ΔV_O DC output load regulation	$V_{OUT} = 0.8\text{ V}$, $0 \leq I_{Load} \leq 0.5\text{ A}$, $T_J = -55^\circ\text{C}^{(2)}$		0.05		mV
	$V_{OUT} = 0.8\text{ V}$, $0 \leq I_{Load} \leq 0.5\text{ A}$, $T_J = 25^\circ\text{C}^{(2)}$		0.05		
	$V_{OUT} = 0.8\text{ V}$, $0 \leq I_{Load} \leq 0.5\text{ A}$, $T_J = 125^\circ\text{C}^{(2)}$		0.07		
	$V_{OUT} = 0.8\text{ V}$, $0 \leq I_{Load} \leq 0.5\text{ A}$, $T_J = 210^\circ\text{C}^{(2)}$		0.51		
	$V_{OUT} = 6.8\text{ V}$, $0 \leq I_{Load} \leq 0.5\text{ A}$, $T_J = -55^\circ\text{C}^{(2)}$		0.10		
	$V_{OUT} = 6.8\text{ V}$, $0 \leq I_{Load} \leq 0.5\text{ A}$, $T_J = 25^\circ\text{C}^{(2)}$		0.04		
	$V_{OUT} = 6.8\text{ V}$, $0 \leq I_{Load} \leq 0.5\text{ A}$, $T_J = 125^\circ\text{C}^{(2)}$		0.05		
	$V_{OUT} = 6.8\text{ V}$, $0 \leq I_{Load} \leq 0.5\text{ A}$, $T_J = 210^\circ\text{C}^{(2)}$		0.47		
V_{DO} Dropout voltage	$I_{OUT} = 0.5\text{ A}$, $V_{OUT} = 6.8\text{ V}$, $V_{IN} = V_{OUT} + 0.1\text{ V}$		55.5	100	mV
I_{CL} Programmable output current limit range	$V_{IN} = 1.5\text{ V}$, $V_{OUT} = 1.2\text{ V}$, PCL resistance = $47\text{ k}\Omega$	500		700	mA
	$V_{IN} = 1.5\text{ V}$, $V_{OUT} = 1.2\text{ V}$, PCL resistance varies	200		700	
V_{CS} Operating voltage range at CS		0.3		V_{IN}	V
CSR Current sense ratio	I_{LOAD} / I_{CS} , $V_{IN} = 2.3\text{ V}$, $V_{OUT} = 1.9\text{ V}$		47394		
I_{GND} GND terminal current	$V_{IN} = 1.5\text{ V}$, $V_{OUT} = 1.2\text{ V}$, $I_{OUT} = 0.5\text{ A}$		13	20	mA
I_Q Quiescent current (no load)	$V_{IN} = V_{OUT} + 0.5\text{ V}$, $I_{OUT} = 0\text{ A}$		12	17	mA
I_{SHDN} Shutdown current	$V_{EN} < 0.5\text{ V}$, $0.8\text{ V} \leq V_{IN} \leq 7\text{ V}$		15	4500	μA
I_{SNS} , I_{FB} FB/SNS terminal current	$V_{IN} = 7\text{ V}$, $V_{OUT} = 6.8\text{ V}$		1	10	nA
I_{EN} EN terminal input current	$V_{IN} = 7\text{ V}$, $V_{EN} = 7\text{ V}$		6.75	610	nA
V_{ILEN} EN terminal input low (disable)	$3.5\text{ V} < V_{IN} < 7\text{ V}$		$0.30 \times V_{IN}$		V

(1) Based upon using 0.1% resistors.

(2) Line and load regulations done under pulse condition for $T < 10\text{ ms}$.

Electrical Characteristics (continued)

$1.5\text{ V} \leq V_{IN} \leq 7\text{ V}$, $V_{OUT(target)} = V_{IN} - 0.3\text{ V}$, $I_{OUT} = 10\text{ mA}$, $V_{EN} = 1.1\text{ V}$, $C_{OUT} = 22\text{ }\mu\text{F}$, PG terminal pulled up to V_{IN} with $50\text{ k}\Omega$, over operating temperature range ($T_J = -55^\circ\text{C}$ to 210°C), unless otherwise noted. Typical values are at $T_J = 25^\circ\text{C}$.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{IHEN}	EN terminal input high (enable)	$3.5\text{ V} < V_{IN} < 7\text{ V}$	$0.75 \times V_{IN}$			V
Eprop Dly	Enable terminal propagation delay	$V_{IN} = 2.2\text{ V}$, EN rise to I_{OUT} rise		650	1000	μs
T_{EN}	Enable terminal turn-on delay	$V_{IN} = 2.2\text{ V}$, $V_{OUT} = 1.8\text{ V}$, $I_{LOAD} = 0.5\text{ A}$, $C_{OUT} = 220\text{ }\mu\text{F}$, $C_{SS} = 2\text{ nF}$		1.4	1.6	ms
V_{THPG}	PG threshold on	No load, $V_{OUT} = 1.2\text{ V}$ and $V_{OUT} = 6.8\text{ V}$	84%	90%		
$V_{THPGHYS}$	PG hysteresis	$1.5\text{ V} \leq V_{IN} \leq 7\text{ V}$		2%		
V_{OLPG}	PG terminal output low	$I_{PG} = 0\text{ mA}$ to -1 mA		73	300	mV
I_{LKGPG}	PG terminal leakage current	$V_{OUT} > V_{THPG}$, $V_{PG} = 7\text{ V}$		0.02	20	μA
I_{SS}	SS terminal current	$V_{IN} = 1.5\text{ V}$ to 7 V		2.5	6.3	μA
I_{SSdisb}	SS terminal disable current	$V_{IN} = 1.5\text{ V}$ to 7 V		5	13	μA
V_{SS}	SS terminal voltage (device enabled)	$V_{IN} = 1.5\text{ V}$ to 7 V			1.2	V
PSRR	Power-supply rejection ratio	$V_{IN} = 2.5\text{ V}$, $V_{OUT} = 1.8\text{ V}$, $C_{OUT} = 220\text{ }\mu\text{F}$	1 kHz	45		dB
			100 kHz	20		
V_N	Output noise voltage	BW = 10 Hz to 100 kHz, $I_{OUT} = 500\text{ mA}$, $V_{IN} = 2\text{ V}$, $V_{OUT} = 1.8\text{ V}$		20.26		μV_{RMS}
T_J	Operating junction temperature		-55		210	$^\circ\text{C}$

6.6 Typical Characteristics

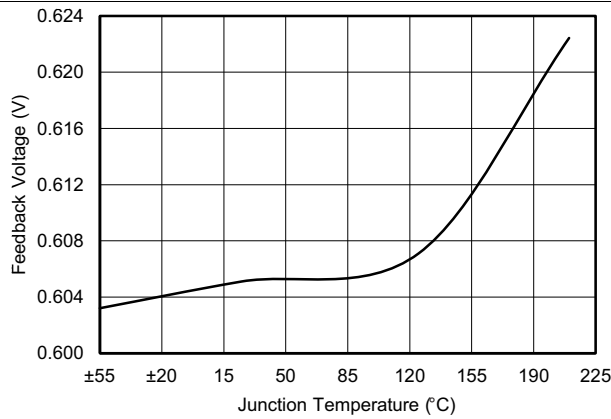


Figure 1. Feedback Voltage vs Temperature

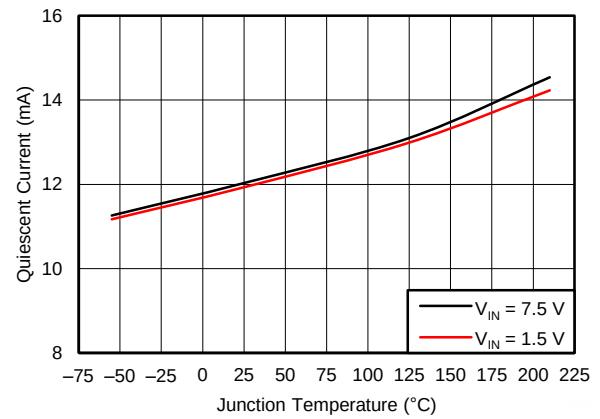


Figure 2. Quiescent Current vs Temperature

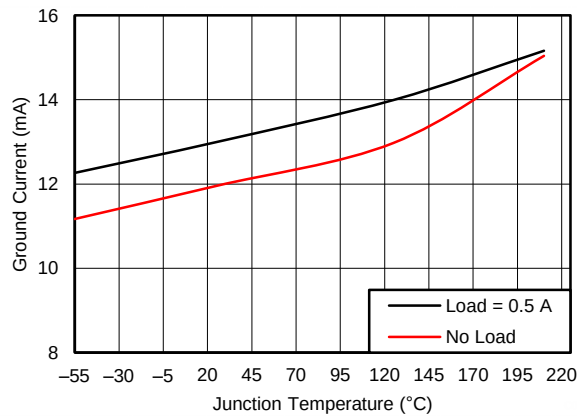


Figure 3. Ground Current vs Temperature

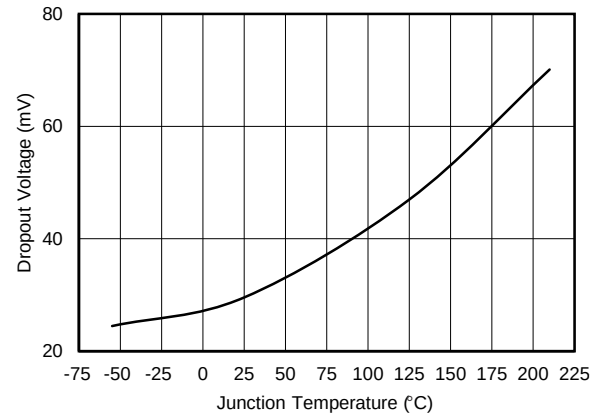


Figure 4. Dropout Voltage vs Temperature

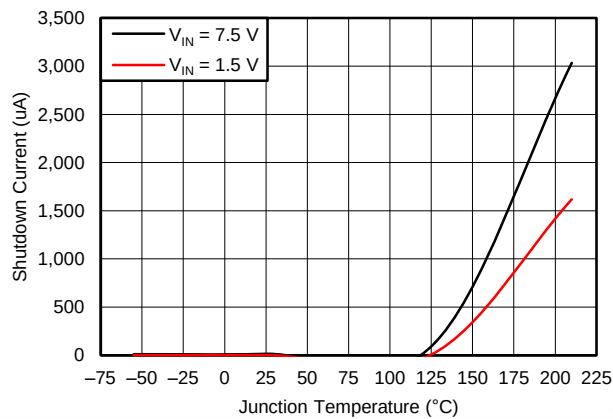


Figure 5. Shutdown Current vs Temperature

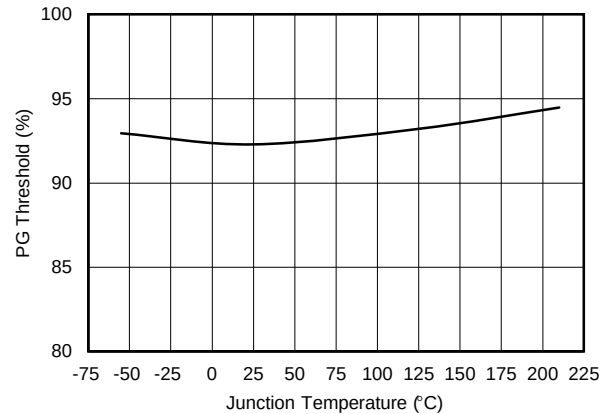


Figure 6. PG Threshold vs Temperature

Typical Characteristics (continued)

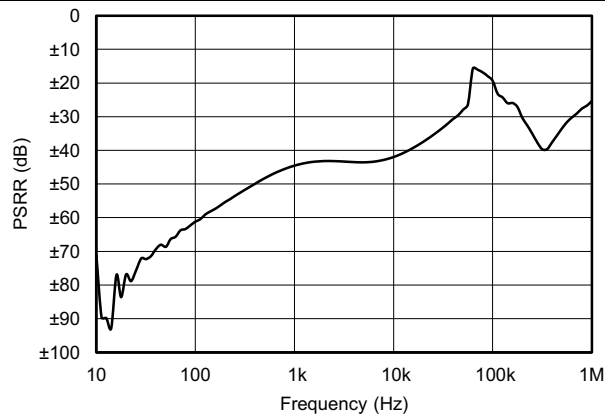


Figure 7. Power Supply Ripple Rejection vs Frequency,
 $I_{OUT} = 250 \text{ mA}$

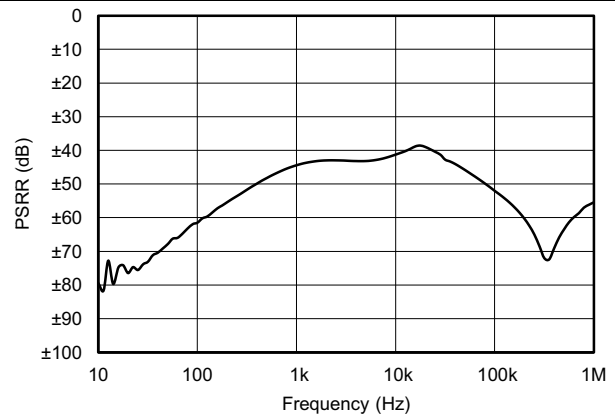


Figure 8. Power Supply Ripple Rejection vs Frequency,
 $I_{OUT} = \text{No Load}$

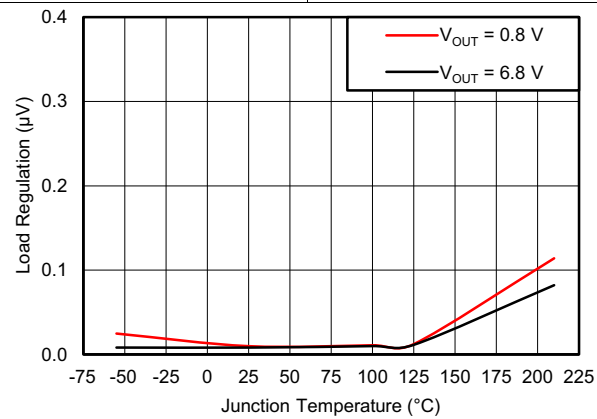


Figure 9. Load Regulation vs Temperature

7.3 Feature Description

7.3.1 Soft Start

Connecting a capacitor from the SS terminal to GND (C_{SS}) slows down the output voltage ramp rate. The soft-start capacitor charges up to 1.2 V.

$$C_{SS} = \frac{t_{SS} \cdot I_{SS}}{V_{FB}}$$

where

- t_{SS} = Soft-start time
- I_{SS} = 2.5 μ A
- $V_{FB} = V_{REF} / 2 = 0.605$ V

(1)

7.3.2 Power Good (PG)

Power Good terminal (9) is an open-drain connection and can be used to sequence multiple LDOs. Figure 11 shows typical connection for $V_{IN} > 3.5$ V. The PG terminal will be pulled low until the output voltage reaches 90% of its maximum level. At that point, the PG pin will be pulled up. Since the PG pin is open drain, it can be pulled up to any voltage as long as it does not exceed the absolute max of 7.5 V listed in the table.

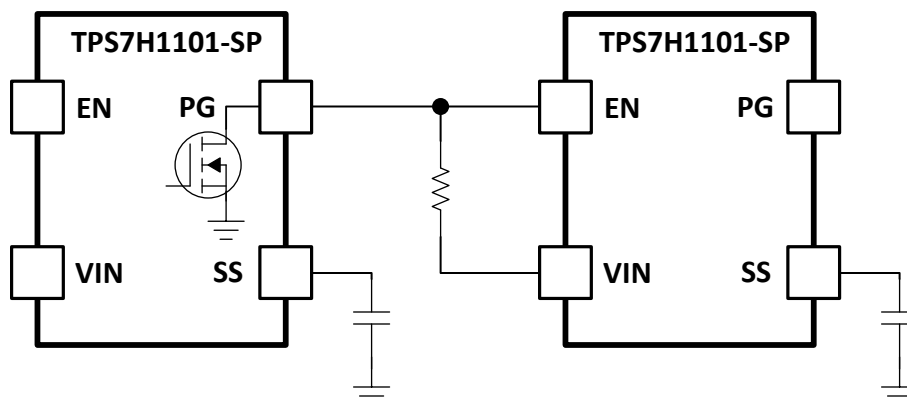


Figure 11. Sequencing LDOs with Power Good

NOTE

For PSpice models, WEBENCH, and mini-POL reference design, see the *Tools & Software* tab.

1. PSpice average model (stability – bode plot)
2. PSpice transient model (switching waveforms)
3. WEBENCH design tool (www.ti.com/product/TPS7H1201-HT/toolssoftware)

7.4 Device Functional Modes

7.4.1 Enable/Disable

For V_{IN} from 1.5 V to 7 V, TPS7H1201-HT can be disabled using the SS terminal. The minimum soft-start pulldown current is 10 μ A, with soft start to ground voltage of 400 mV or lower. External voltage applied to the SS terminal must be limited to 1.2-V maximum. Removing the logic-low condition on soft start enables the device allowing the soft-start capacitor to get charged by the internal current source. Alternatively, for $V_{IN} > 3.5$ V, the device can be disabled by pulling the enable terminal to logic low. In all other cases, the enable terminal should be connected to VIN.

Device Functional Modes (continued)

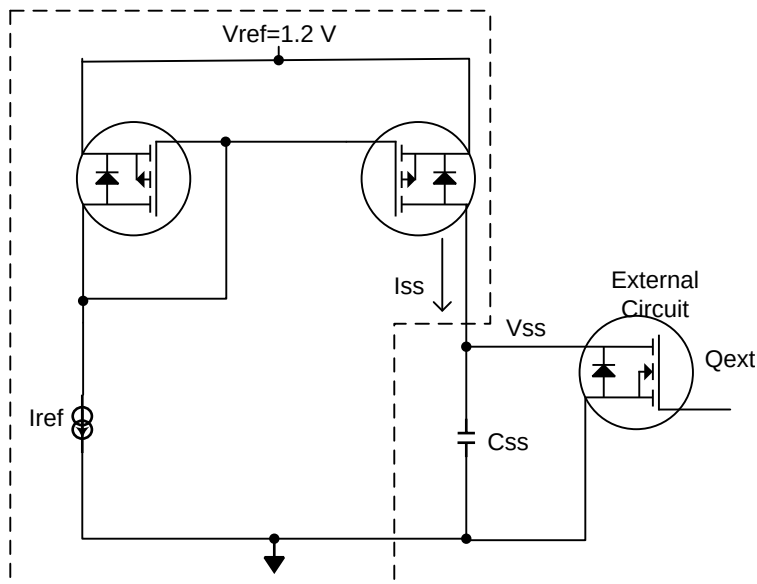


Figure 12. Enable/Disable

The circuit shown in [Figure 12](#) highlights the SS terminal 1 along with block diagram of internal circuitry. Circuitry in dashed outline is internal to the IC composed of PMOSFET current mirror. The PMOS current mirror sources current from the positive supply and external circuitry composed of Qext is used to sink current from SS terminal 1. As highlighted in the table, typical $I_{SS} = 2.5 \mu A$ and max $I_{SS} = 3.5 \mu A$ for TPS7H1101-SP. If I_{SS} current is exceeded, such as sinking higher current in excess of max I_{SS} , this disables the LDO. See the table for the external sink current from SS terminal necessary to disable the IC. Exceeding maximum external sink current does not damage the device.

8 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The TPS7H1201-HT LDO linear regulator is targeted to harsh environment applications. This regulator has various features such as low dropout, soft start, output current foldback, high-side current sensing (where sensing voltage at CS pin provides voltage proportional to output current), and current sharing.

8.1.1 Stability

Conventional Bode plots are a standard approach in assessing stability as shown in Figure 13. This approach requires that we have a single feedback path where an AC signal is injected across a resistor (typically 50 Ω) and measurements are taken on either side of the resistor. From this, loop gain and phase plots can be generated. Crossover frequency, f_c , is defined as the frequency where the magnitude of the loop gain is unity and phase margin is evaluated at the crossover frequency f_c .

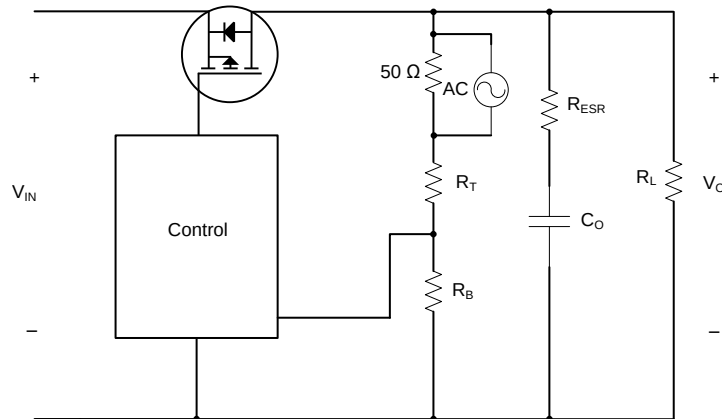


Figure 13. Conventional Bode Plot

However, there are conditions where the feedback loop is not accessible or there may be multiple feedback paths, as with the TPS7H1101-SP. When there are multiple feedback loops the conventional bode plot approach will not be representative of the device's true response. The TPS7H1101-SP uses a conventional feedback loop in addition to an inner fast loop that injects current into the error amplifier, which in turn greatly improves the transient response of the device. The Bode plot method can still be used to understand the behavior of the main loop, but this will show a lower crossover frequency and thus imply a slower transient response than the actual performance of the device. Fortunately, accurate and quantitative stability metrics can still be assessed from output impedance measurements and simulations.

There are multiple ways output impedance can be measured. One approach is to inject a small current at the output of the regulator and compare it to the resulting voltage response. The variation in the phase of the output impedance across frequency can be related to the phase margin through the group delay.

Group delay, T_g , is the rate of change of phase with respect to frequency as shown in Equation 2. Most SPICE simulation packages can plot this parameter and certain frequency analyzers boast software that supports a direct measurement. Using this software, phase margin can be extracted from the group delay plot. The phase margin and crossover frequency reported from these measurements will include the effects of both feedback loops.

$$T_g = \frac{d\phi}{d\omega} \quad (2)$$

Application Information (continued)

The stability of the device can be qualitatively validated by applying a step load to the output and observing the response. The SPICE models for the device can be found in [Tools & Software](#) on the product page. To simulate impedance measurements, the transient model should be used. For a more detailed explanation of this approach and how to use the model to simulate the output impedance and group delay, please see reference (1).

8.2 Typical Application

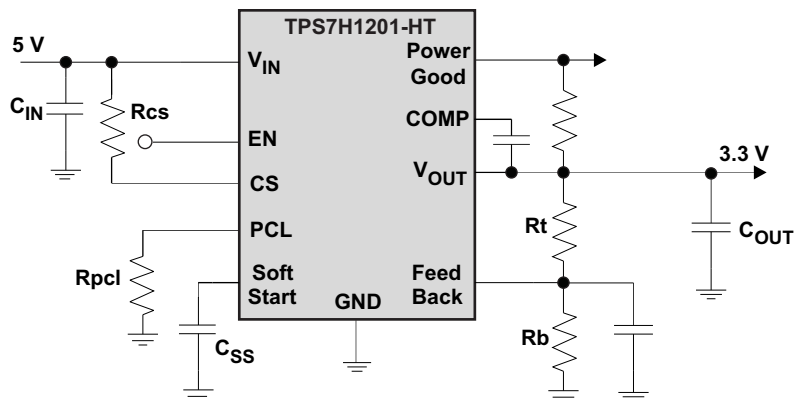


Figure 14. Typical Application Circuit

8.2.1 Design Requirements

[Table 1](#) shows the design parameters.

Table 1. Design Parameters

PARAMETER	VALUE
Input voltage	1.5 V to 7 V
Output voltage	User programmable
Output current	3-A max

8.2.2 Detailed Design Procedure

8.2.2.1 Adjustable Output Voltage (Feedback Circuit)

The output voltage of the TPS7H1201-HT can be set to a user-programmable level between 0.8 and 6.8 V. Achieve this by using a resistor divider connected between V_{OUT} , FB, and GND terminals. R_{TOP} connected between V_{OUT} and V_{FB} , and R_{BOTTOM} connected between V_{FB} and GND.

Use Equation 3 to determine V_{OUT} .

$$V_{OUT} = \frac{(R_{TOP} + R_{BOTTOM}) \cdot V_{FB}}{R_{BOTTOM}}$$

where

- $V_{FB} = 0.605 \text{ V}$ (3)

Table 2. Resistor Values for Typical Voltages

V_{OUT}	Standard 1% Resistors		Standard 0.1% Resistors	
	R_{TOP}	R_{BOTTOM}	R_{TOP}	R_{BOTTOM}
0.8 V	10.7 k Ω	33.2 k Ω	10.7 k Ω	33.2 k Ω
1 V	13.7 k Ω	21 k Ω	12.6 k Ω	19.3 k Ω
1.2 V	11.3 k Ω	11.5 k Ω	11.8 k Ω	12 k Ω
1.5 V	15.8 k Ω	10.7 k Ω	18.2 k Ω	12.3 k Ω
1.8 V	23.2 k Ω	11.8 k Ω	32 k Ω	16.2 k Ω
2.5 V	10.7 k Ω	3.4 k Ω	37.9 k Ω	12.1 k Ω
3.3 V	51.1 k Ω	11.5 k Ω	10.2 k Ω	2.29 k Ω
4 V	13.3 k Ω	2.37 k Ω	31.2 k Ω	5.56 k Ω
5 V	11.5 k Ω	1.58 k Ω	16.2 k Ω	2.23 k Ω
5.5 V	17.4 k Ω	2.15 k Ω	89.8 k Ω	11.1 k Ω
6 V	90.9 k Ω	10.2 k Ω	10.7 k Ω	1.2 k Ω
6.5 V	26.7 k Ω	2.74 k Ω	15.2 k Ω	1.56 k Ω
6.6 V	11.3 k Ω	1.15 k Ω	22.1 k Ω	2.23 k Ω
6.7 V	39.2 k Ω	3.92 k Ω	13.8 k Ω	1.37 k Ω

8.2.2.2 PCL

PCL resistor, R_{pcl} , sets the overcurrent limit activation point and can be calculated per Equation 4.

$$R_{pcl} = (CSR \times V_{ref}) / (I_{CL} - 0.0403)$$

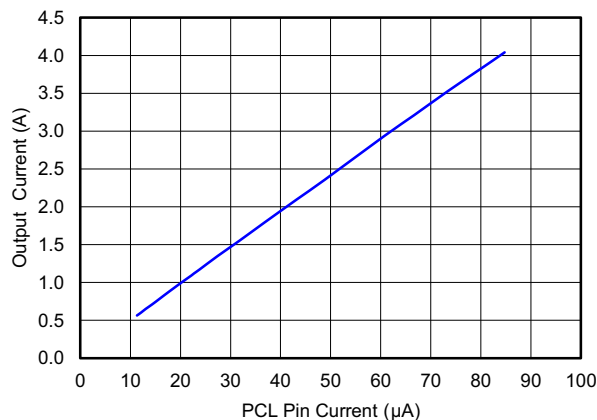
where

- $V_{ref} = 0.605 \text{ V}$
- I_{CL} = Programmable current limit (A)
- Current sense ratio (CSR) is the ratio of output load current to I_{CS} . The typical value of the CSR is 47394. (4)

Figure 15 shows the output load current (I_{OUT}) versus PCL terminal current (I_{CL})

A suitable resistor R_{pcl} must be chosen to ensure the CS terminal is within its operating range of 0.3 V to V_{IN} .

The maximum PCL is 700 mA. The range of resistor that can be used on the PCL terminal to GND is 47 k Ω to 160 k Ω .



$$V_{IN} = 2.3 \text{ V} \quad V_{OUT} = 1.8 \text{ V} \quad y = 47394x + 0.0403$$

Figure 15. I_{OUT} (A) vs I_{PCL} (μA)

8.2.2.3 High-Side Current Sense

Figure 16 shows the cascode NMOS current mirror. V_{CS} must be in the range as specified in the [Electrical Characteristics](#) table. The following example shows the typical calculation of R_{CS} .

$$I_{CS} = \frac{I_{LOAD} + I_{offset}}{CSR} \quad (5)$$

$$R_{CS} = \frac{V_{IN} - V_{CS}}{I_{CS}}$$

where

- I_{LOAD} is the output load current.
- CSR is the current sense ratio.

(6)

When $V_{IN} = 2.3 \text{ V}$, select $V_{CS} = 2.05 \text{ V}$, $I_{LOAD} = 3 \text{ A}$, $CSR = 47394$, and $I_{offset} = 0.1899 \text{ A}$, then $I_{CS} = 67.306 \mu\text{A}$ and $R_{CS} = 3.714 \text{ k}\Omega$.

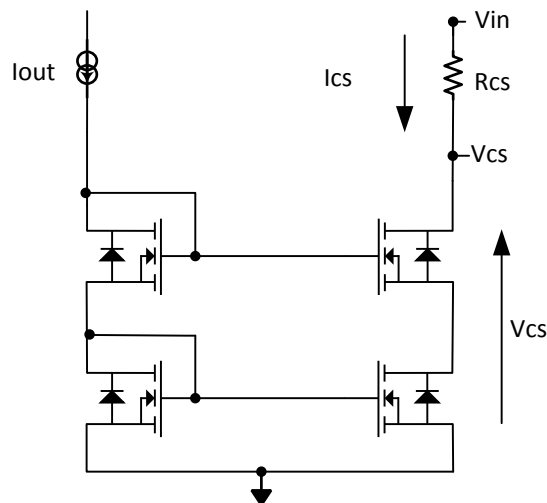
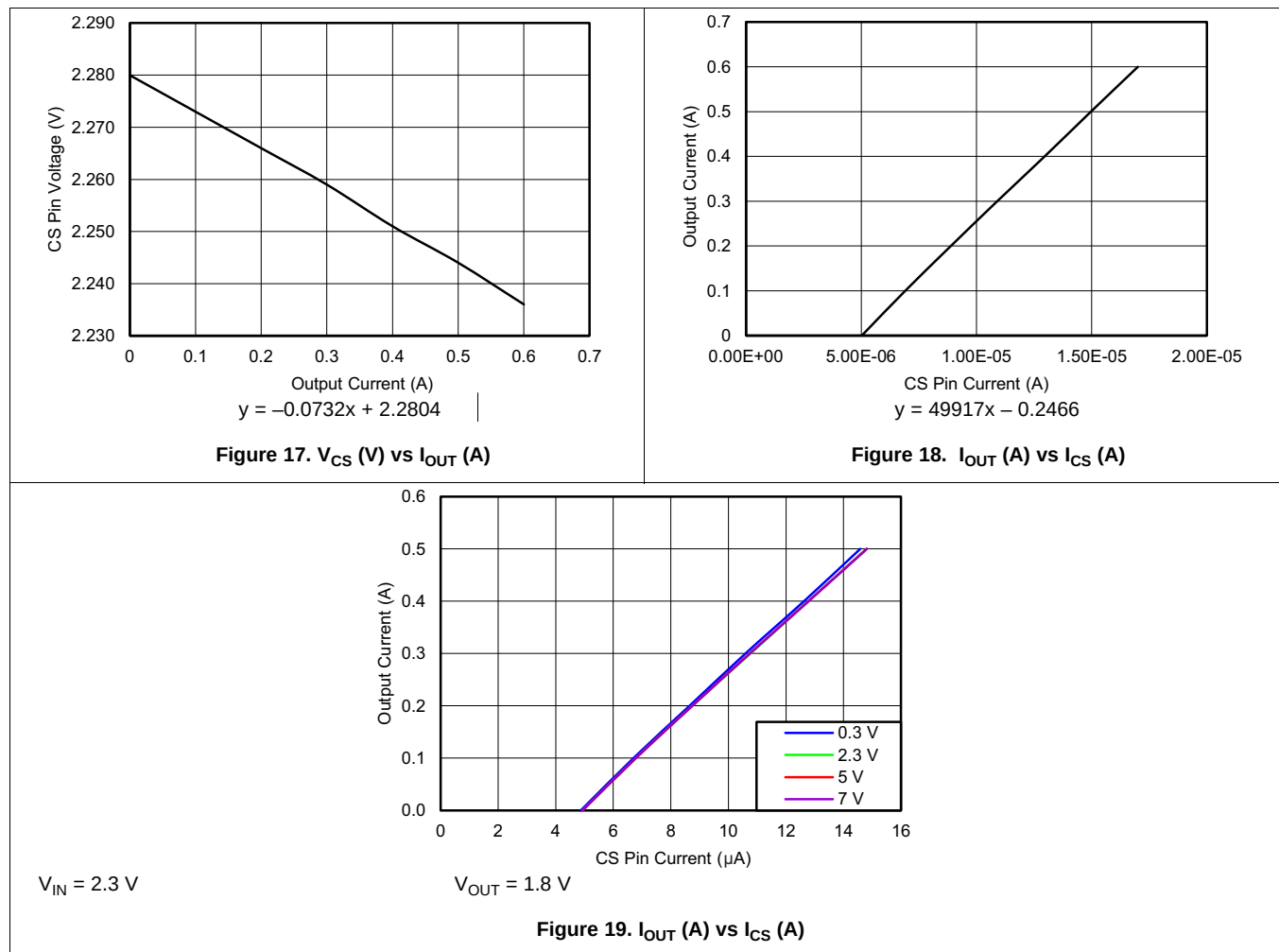


Figure 16. Cascode NMOS Current Mirror

For TPS7H1201-HT, Figure 17 shows the typical curve V_{CS} vs I_{OUT} for $V_{IN} = 2.28 \text{ V}$ and $R_{CS} = 3.65 \text{ k}\Omega$. A resistor connected from the CS terminal to V_{IN} indicates voltage proportional to the output current.

Monitoring current in the CS terminal (I_{CS} vs I_{OUT}) indicates the current sense ratio between the main PMOSFET and the current sense MOSFET as shown in .

Figure 19 shows I_{OUT} vs I_{CS} when the voltage on CS terminal is varied from 0.3 V to 7 V.



8.2.2.4 Current Foldback

1. The TPS7H1201-HT has a current foldback feature which can be enabled when the CS terminal is held high. Shorting CS low disables the foldback current limit. If the foldback current limit is disabled, then the LDO will begin regulating again as soon as the current falls below the clamp threshold.
2. With foldback current limit enabled, when current limit trip point is activated,
 - (a) Output voltage drops low.
 - (b) Output current folds back to approximately 50% of the current limit trip point.
 This results in minimizing the power loss under fault conditions. Monitoring the voltage at the CS terminal indicates voltage proportional to the output current.

8.2.2.5 Transient Response

Figure 20, Figure 21, and Figure 22 indicate the transient response behavior of the TPS7H1201-HT.

Channel 1: Output voltage overshoot/undershoot

Channel 2: Step load in current

Channel 3: Input voltage

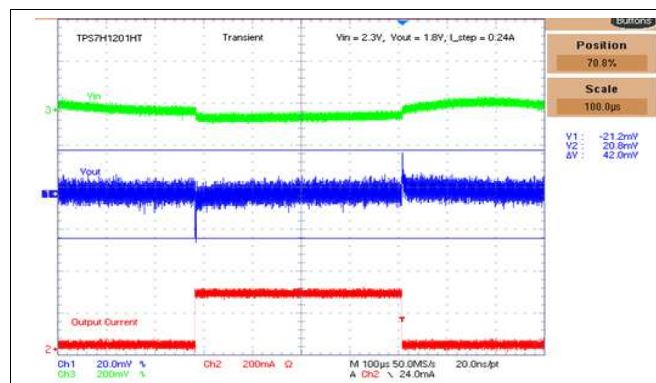


Figure 20. Load Transient Response: Step Load 0 A to 250 μ A, V_{IN} = 2.3 V, V_{OUT} = 1.8 V

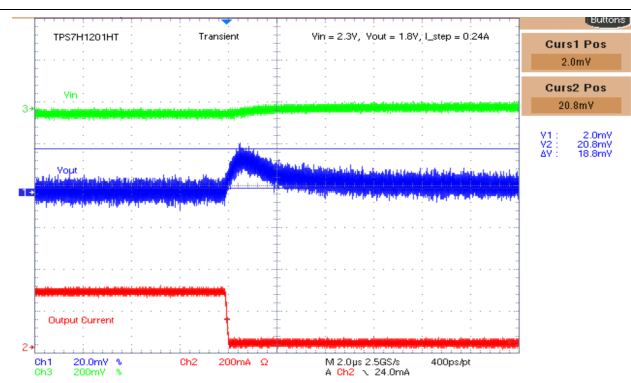


Figure 21. Expanded View Overshoot

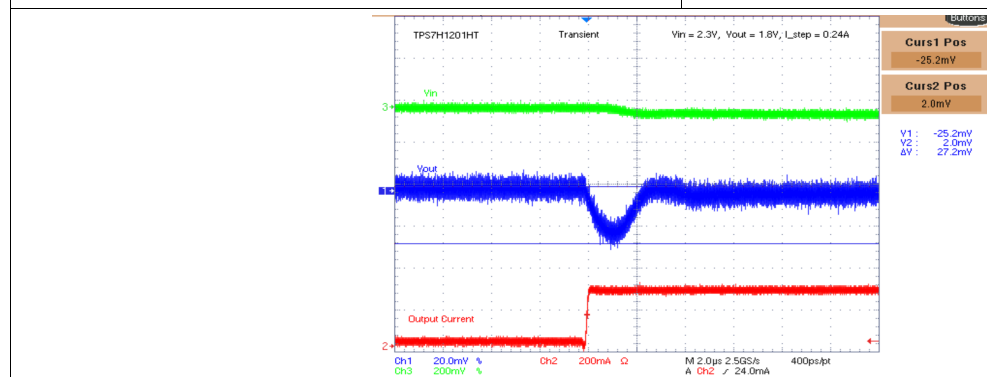


Figure 22. Expanded View Undershoot

8.2.2.6 Current Sharing

For demanding load requirements, multiple LDOs can be paralleled as indicated in [Figure 24](#). In parallel mode, the CS terminal of LDO1 must be connected to the PCL terminal of LDO2 via a series resistor R_{CL} , and CS terminal of LDO2 must be connected to PCL terminal of LDO1 via series resistor R_{CL} . The typical value of R_{CL} in parallel operation is 3.75 k Ω for current limit > 6 A. In parallel configuration, R_{CL} (resistor from PCL to GND) and R_{CS} (resistor from CS terminal to V_{IN}) must be left open (unpopulated). The R_{CL} value must be selected so that the operating condition of the CS terminal is maintained, as specified in the [Electrical Characteristics](#) table. The current from PCL through R_{CL} of LDO1 is determined by the output load current of LDO2 divided by the CSR. Hence, the voltage at CS terminal of the LDO1 is 0.605 V – ((output load current of LDO2 + 0.2458) / CSR $\times$ R_{CL}).

Alternately, it can also provide twice the output current to meet system needs. When using two LDOs in parallel operation for higher output load current, use POL TPS50601-SP as an input source.

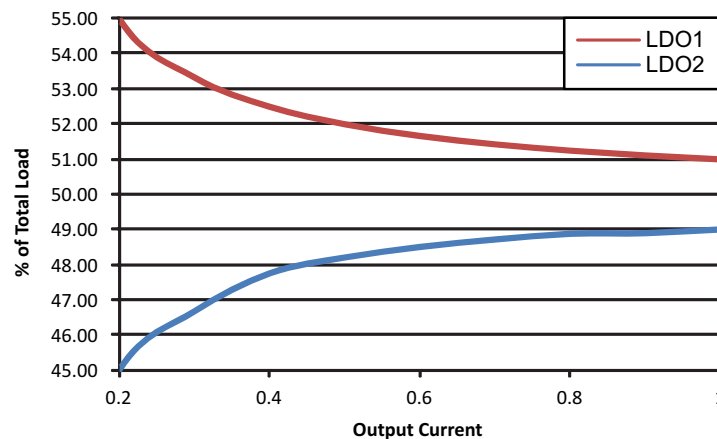


Figure 23. LDO Current Share

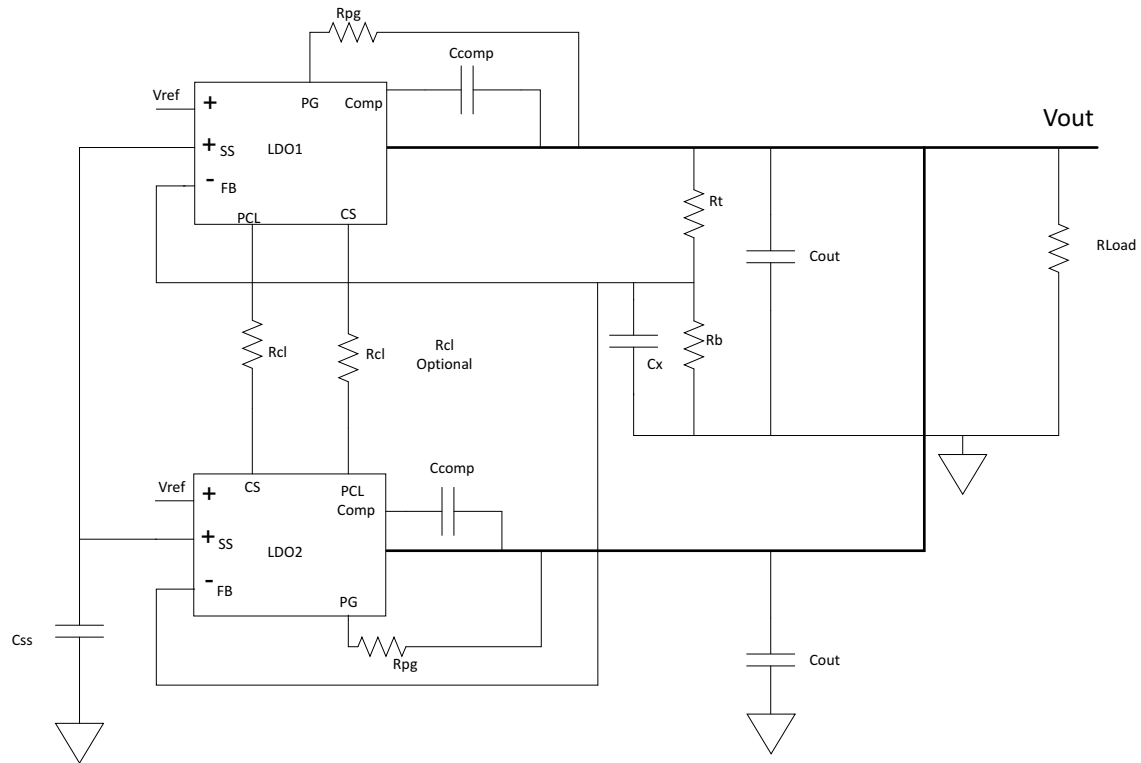


Figure 24. Block Diagram (Parallel Operation)

8.2.2.7 Compensation

Figure 25 shows a generic block diagram for TPS7H1201-HT LDO with external compensation components. LDO incorporates nested loops, thus providing the high gain necessary to meet design performance.

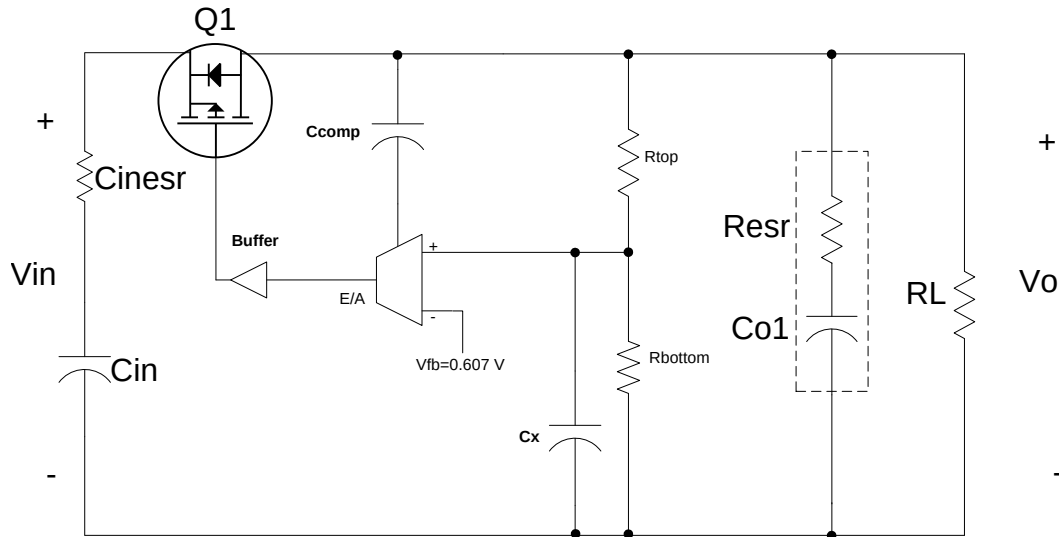


Figure 25. TPS7H1201-HT Compensation

Resistor divider composed of R_{top} and R_{bottom} determine the output voltage set points as indicated by Equation 3.

Output capacitor C_{OUT} introduces a pole and a zero as shown in the following.

$$F_{p_{co}} = \frac{1}{2 \cdot \pi \cdot C_o \cdot R_L} \quad (7)$$

$$F_{z_{co}} = \frac{1}{2 \cdot \pi \cdot C_o \cdot C_{esr}} \quad (8)$$

The TPS7H1101-SP was designed so that the ESR of the output capacitor will not have a strong influence on the response of the LDO. However, an optional capacitor, C_x , can be added in parallel with the bottom feedback resistor to introduce a pole to cancel $F_{z_{co}}$. Equation 9 shows how to calculate the location of the pole introduced by C_x . To cancel the zero directly, F_p should be equal to $F_{z_{co}}$.

$$F_p = \frac{1}{2 \cdot \pi \cdot C_x \cdot R_{bottom}} \quad (9)$$

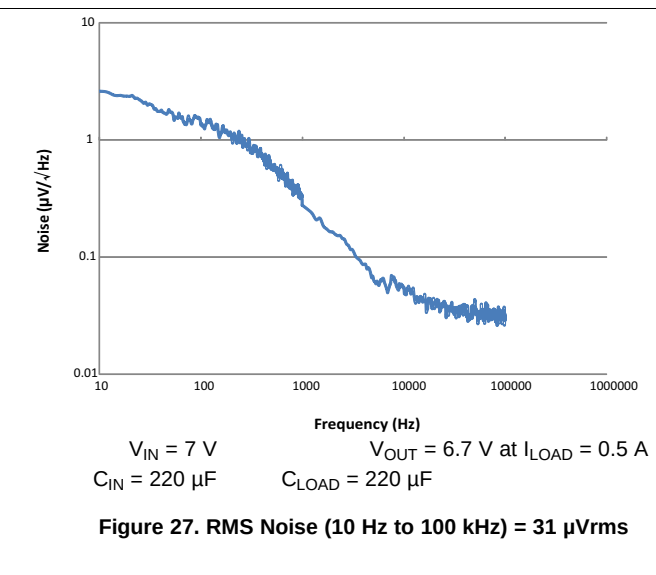
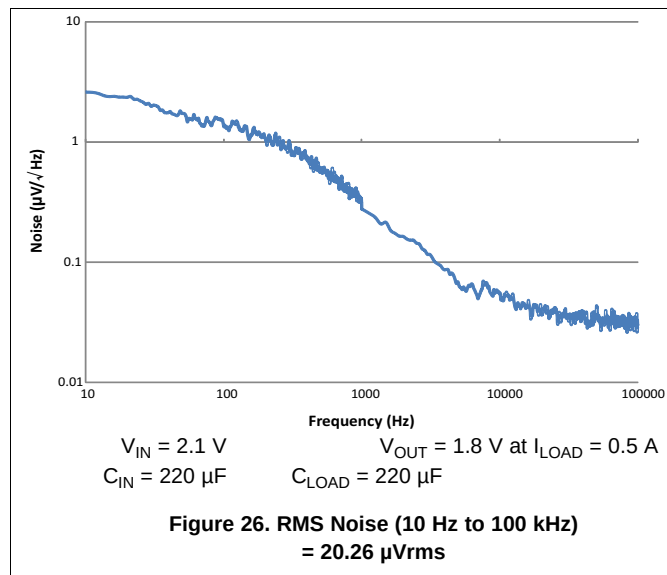
C_x is calculated to be 1000 pF for $C_o = 220 \mu F$, $C_{esr} = 45 m\Omega$, and $R_{bottom} = 10 k\Omega$.

Internal compensation in the LDO cancels the output capacitor pole introduced by C_{OUT} and R_L .

C_{comp} introduces a dominant pole at low frequency. TI recommends that a C_{comp} value of 10 nF.

8.2.2.8 Output Noise

Output noise is measured using an HP3495A. , , Figure 26, and Figure 27 show noise of the TPS7H1201-HT in $\mu V/\sqrt{Hz}$ vs frequency.



8.2.2.9 Capacitors

TPS7H1201-HT requires the use of a combination of tantalum and ceramic capacitors to achieve good volume to capacitance ratio. [Table 3](#) highlights some of the capacitors used in the device. TI recommends to follow proper derating guidelines as recommended by the capacitor manufacturer based upon output voltage and operating temperature.

Note that polymer-based tantalum capacitors must be derated to at least 60% of rated voltage, whereas manganese oxide (MnO_2) based tantalum capacitors should be derated to 33% of rated voltage depending upon the operating temperature.

TI recommends to use a tantalum capacitor along with a 0.1- μF ceramic capacitor. The device is stable for input and output tantalum capacitor values of 10 to 220 μF with the ESR range of 10 m Ω to 2 Ω . However, the dynamic performance of the device varies based on load conditions and the capacitor values used.

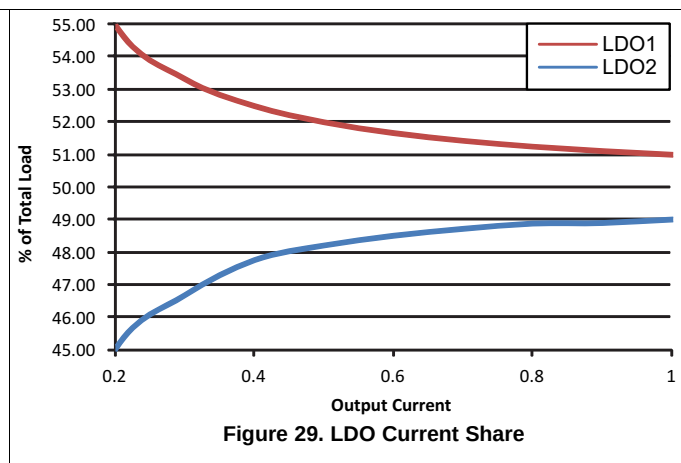
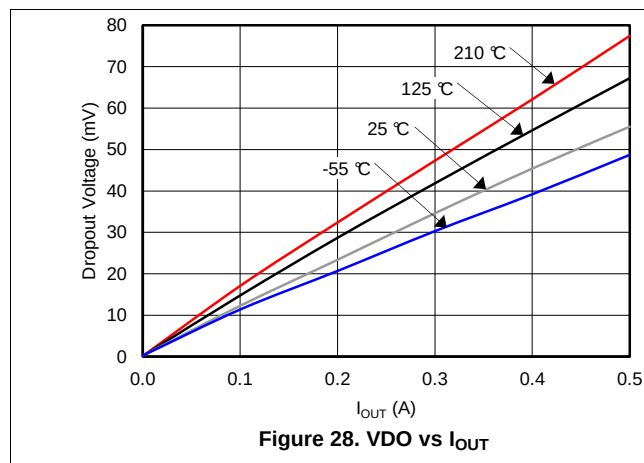
TI recommends a minimum output capacitor of 22 μF with ESR of 1 Ω or less to prevent oscillations. X7R dielectrics are preferred. See [Table 3](#) for various capacitor recommendations.

Table 3. TPS7H1201-HT Capacitors

CAPACITOR PART NUMBER	CAPACITOR DETAILS (CAPACITOR, VOLTAGE, ESR)	TYPE	VENDOR
T493X107K016CH612A ⁽¹⁾	100 μ F, 16 V, 100 m Ω	Tantalum - MnO ₂	Kemet
T493X226M025AH6x20 ⁽¹⁾	22 μ F, 25 V, 35 m Ω	Tantalum - MnO ₂	Kemet
T525D476M016ATE035 ⁽¹⁾	47 μ F, 10 V, 35 m Ω	Tantalum - Polymer	Kemet
T540D476M016AH6520 ⁽¹⁾	47 μ F, 16 V, 20 m Ω	Tantalum - Polymer	Kemet
T525D107M010ATE025 ⁽¹⁾	100 μ F, 10 V, 25 m Ω	Tantalum - Polymer	Kemet
T541X337M010AH6720 ⁽¹⁾	330 μ F, 10 V, 6 m Ω	Tantalum - Polymer	Kemet
T525D227M010ATE025 ⁽¹⁾	220 μ F, 10 V, 25 m Ω	Tantalum - Polymer	Kemet
T495X107K016ATE100 ⁽¹⁾	100 μ F, 16 V, 100 m Ω	Tantalum - MnO ₂	Kemet
CWR29FK227JTHC ⁽¹⁾	220 μ F, 10 V, 180 m Ω	Tantalum - MnO ₂	AVX
THJE107K016AJH	100 μ F, 16 V, 58 m Ω	Tantalum	AVX
THJE227K010AJH	220 μ F, 10 V, 40 m Ω	Tantalum	AVX
SMX33C336KAN360	33 μ F, 25 V	Stacked ceramic	AVX
SR2225X7R335K1P5#M123	3.3 μ F, 25 V, 10 m Ω	Ceramic	Presidio Components Inc

(1) Operating temperature is -55°C to 125°C .

8.2.3 Application Curves



9 Power Supply Recommendations

This device is designed to operate with an input voltage supply up to 7 V. The minimum input voltage should provide adequate headroom greater than the dropout voltage for the device to have a regulated output. If the input supply is noisy, additional input capacitors with low ESR can help improve the output noise performance.

10 Layout

10.1 Layout Guidelines

- For best performance, all traces should be as short as possible, and no longer than 5 cm.
- Use wide traces for IN, Out and GND to minimize the parasitic electrical effects.
- Place the output capacitors (COUT) as close as possible to the OUT pin of the device.

10.2 Layout Example

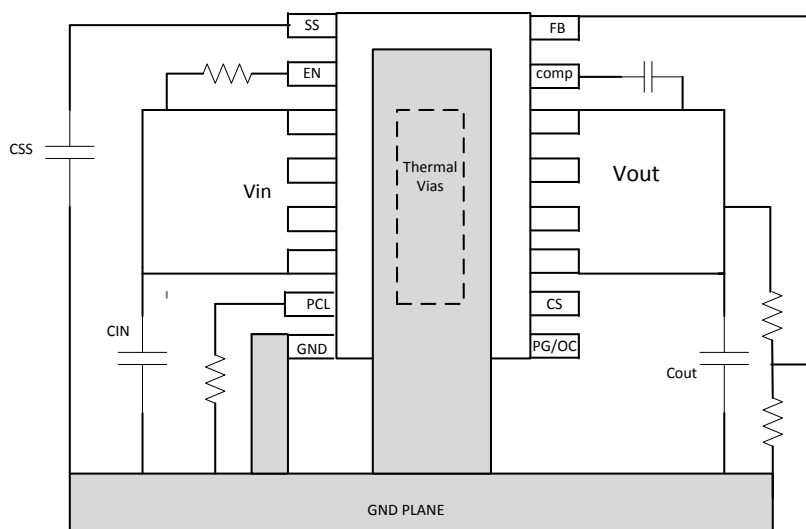


Figure 30. PCB Layout Example

11 Device and Documentation Support

11.1 Device Support

11.1.1 Third-Party Products Disclaimer

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11.1.2 Device Nomenclature

KGD Known good die

11.2 Documentation Support

11.2.1 Related Documentation

(1) [Stability Assessment of Fixed Regulators - Tom Boehler, Paul Ho, AEI Systems](#)

11.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

11.4 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

TI E2E™ Online Community *TI's Engineer-to-Engineer (E2E) Community*. Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support *TI's Design Support* Quickly find helpful E2E forums along with design support tools and contact information for technical support.

11.5 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

11.6 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

11.7 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package Pins	Package qty Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
TPS7H1201SHKS	Active	Production	CFP (HKS) 16	15 TUBE	Yes	NIAU	N/A for Pkg Type	-55 to 210	TPS7H1201SHKS
TPS7H1201SKGD1	Active	Production	XCEPT (KGD) 0	70 NOT REQUIRED	Yes	Call TI	N/A for Pkg Type	-55 to 210	

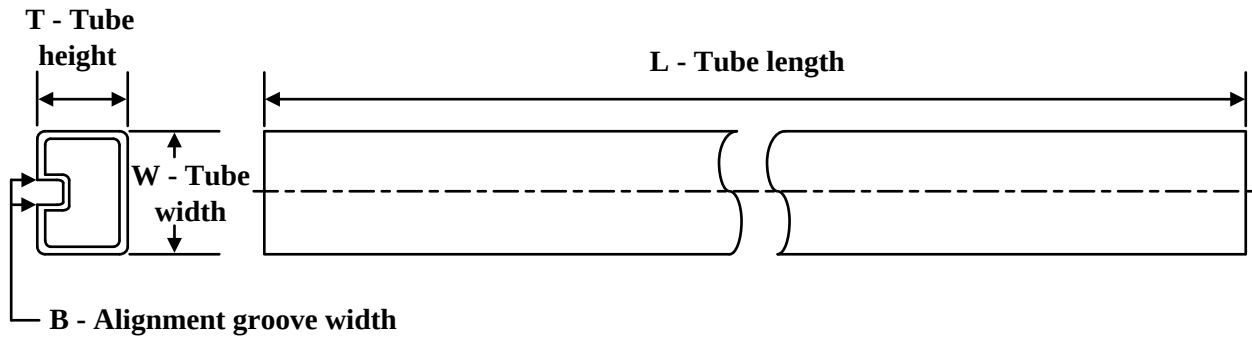
- ⁽¹⁾ **Status:** For more details on status, see our [product life cycle](#).
- ⁽²⁾ **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.
- ⁽³⁾ **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.
- ⁽⁴⁾ **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.
- ⁽⁵⁾ **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.
- ⁽⁶⁾ **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

Important Information and Disclaimer:The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TUBE



*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (μm)	B (mm)
TPS7H1201SHKS	HKS	CFP	16	15	506.98	26.16	6220	NA



PACKAGE OUTLINE

CFP - 3.02 mm max height

CERAMIC FLATPACK



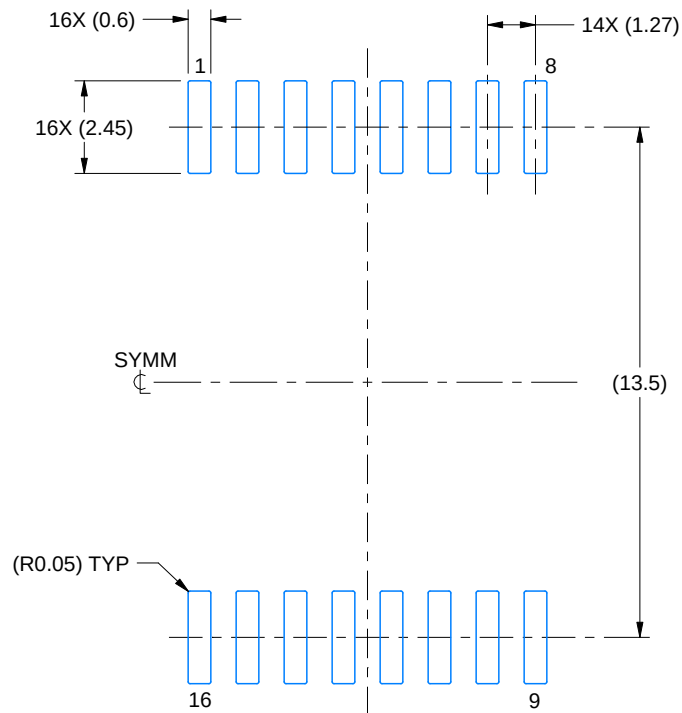
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This package is hermetically sealed with a metal lid. The lid and heat slug are connected to pin 8.
4. The leads are gold plated.

EXAMPLE BOARD LAYOUT

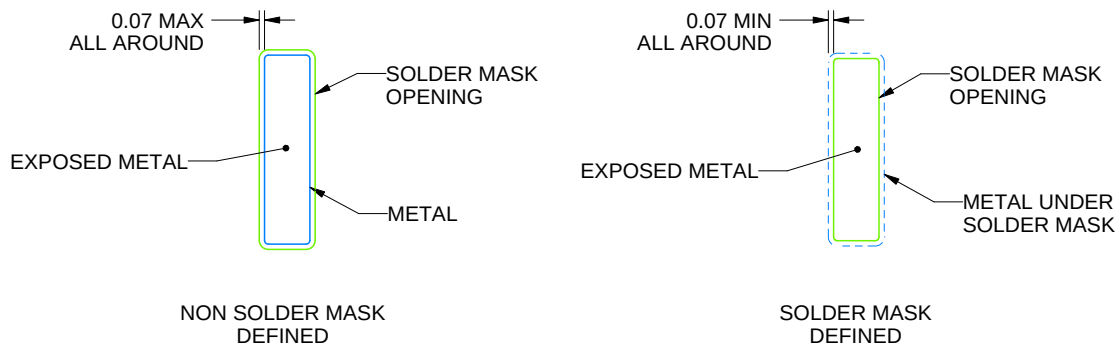
HKS0016A

CFP - 3.02 mm max height

CERAMIC FLATPACK



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 5X



SOLDER MASK DETAILS
NOT TO SCALE

4219258/A 02/2017

NOTES: (continued)

5. Publication IPC-7351 may have alternate designs.

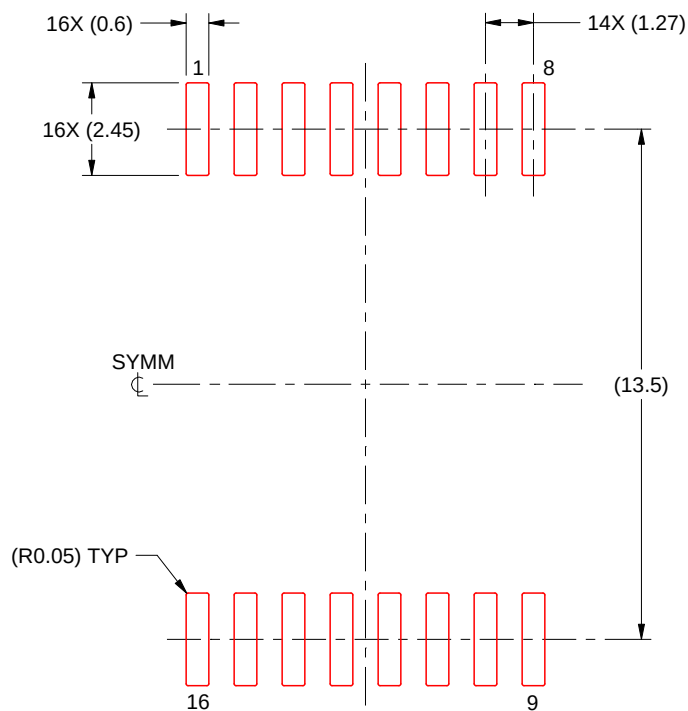
6. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

HKS0016A

CFP - 3.02 mm max height

CERAMIC FLATPACK



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE: 5X

4219258/A 02/2017

NOTES: (continued)

7. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
8. Board assembly site may have different recommendations for stencil design.

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Last updated 10/2025